TECHNICAL REPORT #20

From The Crawford Hill VHF Club Date, December 1986; (New)

Subjects Method for Estimating Receiver Noise Temperature

in an earlier version of Technical Report #11,a method was described to determine the receiver noise temperature by comparison with a room temperature termination. This new Report will elaborate and attempt to eliminate some deficiencies in the method described earlier. Some of the text will be repeated here.

It should be expressly noted here that these measurement procedures should be employed mainly as diagnostic techniques in order to determine where improvements are needed in the EME system.

While a direct measurement of receiver NF using calibrated laboratory test equipment may seem like an accurate determination of the receiver (at least preamplifier) noise performance, it is not always indicative of exactly how well the preamplifier (receiver) is performing in your system. This may be largely due to the impedance presented to the preamplifier by your antenna as compared with what the impedance of the noise generator is when used to measure its NF. In general a good laboratory noise generator may look' like a broadband 50 ohm resistive source while your antenna may be approximately a 50 ohm (narrow band) source. Furthermore. since the preamplifier can be optimized (if adjustments are provided) when connected to a good 50 ohm source impedance. there is no guarantee that it will be optimized when connected to your antenna. Finally. the input noise temperature (and possibly gain) of a low noise preamplifier is characteristically dependent mainly upon input source impedance. and possibly output load impedance. For these reasons, reasonable precautions must be taken to optimize the preamplifier when connected in normal fashion to your antenna.

Optimizing Receiver Antenna Interface

If there is any doubt of the impedance match to the antenna, the following procedure may be used to optimize the complete receiver-antenna interface connection.

This procedure will require a low noise impedance tuner of the type described in Report #12; or, a preamplifier with input matching adjustments. Do not use a stub tuner or any tuner with sliding metal-to-metal contacts as these can be erratic and lossy when adjusted. The dielectric slug tuner described in Report #12 is ideally suited because it is low loss and has a limited impedance transforming range. The rest of the procedure assumes that the preamplifier input is mat adjustable.

Install this tuner between the antenna port and the preamplifier input.If you have a protective relay in front of the preamplifier in normal use. leave it in place and install the tuner between the relay and antenna port.

As a general rule, never install a filter between the antenna port and the preamplifier unless intolerable interference exists. The unavoidable filter losses will degrade the system performance as well as result in extreme impedance match out-of-band.

Next a weak and well shielded signal source is needed to leak a small r-f signal into the antenna system. A good shielded source can be made from a battery operated crystal oscillator and harmonic generator all enclosed in a new paint can as a shielded enclosure. A coaxial port on the shield can be equipped with a small pick-up loop which can be rotated to adjust the output level. The output is then connected to a dipole or horn radiating device radiating directly into the antenna structure. For a parabolic reflector antenna system the weak signal source may be introduced at the vertex of the paraboloid with a small horn or dipole.

The signal source shielding is necessary to prevent stray radiation from reaching the receiver through any path other than directly into the antenna port feeding the preamplifier. A test for leakage should be made when the weak signal level is adjusted to about 10 db above the noise. Simply disconnect the Preamplifier from the antenna and terminate the preamplifier with a well shielded resistive termination and check for signal at the receiver output. If a signal is heard, leakage is present and should be traced down and eliminated before proceeding. With the weak signal feeding the antenna

system, the preamplifier connected in normal fashion and the slug tuner installed, the optimization procedure is simply to measure the signal-to-noise ratio at the receiver output while adjusting the tuner for maximum signal-to-noise. The process may be made more convenient if the weak signal source is automatically keyed "ON" and "OFF" at a regular rate of about once a second (key the harmonic generator to avoid frequency "chirp"), and a level meter is wired to the receiver output and located at the tuner site.

If no improvement can be made, the interface impedance may be correct and the tuner may be removed, checking the S/N ratio again after removing the tuner. If an improvement is noted, even slightly, it will be necessary to either leave the tuner in the operating system or provide other adjustments to the preamplifier input circuit to facilitate matching without the tuner installed. This completes the preamplifier-antenna interface optimization. Don't be surprised if a very noticeable improvement was made, this only indicates the sensitivity of this interface in your set-up and the lack of proper initial adjustment to both preamplifier and antenna feed port match.

If the tuner slug positions indicate maximum mismatch (slugs separated by a quarter wavelength of air coax), then it would be advisable to readjust the antenna input impedance and repeat the noise matching procedure.

Do not use connectors and/or jumper cables of different impedance levels (50/70 ohm) anywhere in and around the antenna-preamplifier interface. Use only double shielded coaxial cable or rigid line for short Jumpers at frequencies above 432 mc/s.

#20 **Receiver**

Noise Temperature Estimation

This measurement procedure is specifically tailored to an antenna system which uses a feed antenna and a focusing reflector.

A good measure of the receiver noise temperature alone may be made using the procedure of switching between the antenna feed and an ambient temperature termination. The procedure will be modified here to minimize the antenna noise effects and to assure that the ambient temperature termination is properly optimized with the preamplifier.

This method is a 'hot-cold' load method with input impedance optimization.

The termination in this case will actually be a matched attenuator of over 30 db loss. The reason for using a matched attenuator instead of a direct termination is to permit a weak signal to be introduced into the receiving system through the attenuator for optimization (using a low loss tuner with the attenuator only). It is assumed that the antenna teed-receiver interface was optimized already.

To minimize teed antenna noise, the feed is removed intact from the reflector antenna and relocated at the vertex of the antenna and positioned to radiate maximum alone the center line of the paraboloid. In this position and with the paraboloid in its stow position trim horizontal) the paraboloid acts as a shield for the eed allowing it no access to warm Earth noise and aimed towards the zenith where the Universe temperature is very low at 1296 mc/s and higher bands the procedure is illustrated by Figure 1 alone with required switching-and-terminating-devices.

Normal feed support struts should be removed it possible the optimizing S/N procedure as described above may now be used with the terminating attenuator switched to the preamplifier. And. for accuracy, the feed-preamplifier interface may be reoptimized by introducing the weak signal over the rim of the dish. There may be some slight interaction when the feed is optimized with and without the active reflector because of reflections into the feed when normally installed. With circular polarization, this effect should be negligible.

Under the conditions illustrated by Figure 1, there should be a very noticeable change in receiver output noise when the preamplifier is switched from feed to attenuator (termination), weak signal turned "OFF", of course. The ratio of output noise change can be related to temperatures by the following formula:

$$\text{Noise Ratio (R)} = \frac{Tr + To}{Tr + T{+}1 + Tuniverse} > 1$$

Tr is the receiving system noise temperature. (universe is the background Universe temperature which is of the order less than 10 decrees K at 1296 mc/s and higher frequency bands an the "space window". T+1 is the feed heat losses and wall be assumed to be small, of the order of the Universe background temperature. or less.

Rearranging the equation to solve for Tr gives

$$T_{\text{receiver system}} = \frac{To - R\,Tu}{R - 1}$$

where Tu is assumed to be of the order 20 degrees Kelvin maximum (backoround plus feed losses) and To is the ambient temperature of the matched attenuator measured with a thermometer. The conversion to the absolute temperature (Kelvin scale) is 273 + C. C is the temperature in degrees celcius.
As an example, if C = 17 deg. celcius. To is 290 degrees and with Tu = 20 and an expected receiver system noise-figure of 1 db (75 deg. K), then the expected value of R will be about 5.8 db. If the procedure is carried out properly then the determination of the receiver noise temperature, Tr. will be dependent on how accurate To and Tu are known. Since Tu embodies the feed antenna loss temperature. Tf1, as well as the Universe background temperature, the determination is not truly complete.
When the feed temperature due to losses in the feed are more than the background temperature, lower values of the ratio R will be observed and Tr will be higher than expected by about the temperature of the feed due to losses. ' If this is the case in your measurements, then the feed should be suspect. Look for poor solder joints, cold solder joints, use of lossy materials in construction, faulty seams, etc. A well constructed feed made from good conductive material should not have more than 0.1 db loss (7.5 degrees K). An interconnecting cable and connectors may have as much or more loss than the feed itself and should be included as part of the antenna temperature if it is between the antenna port and the switching device.

It will be advantageous, when installing the feed back into the reflector antenna, to retain the receiver antenna-to-termination switch both as r-f overload protection, and as a simple check of system performance. When the system is in its normal EME receiving mode, a record of the noise level change when switching from termination to antenna should be made with the antenna aimed at a 'cold' place in the Universe. This level change should be used as a reference to check system performance from time to time.

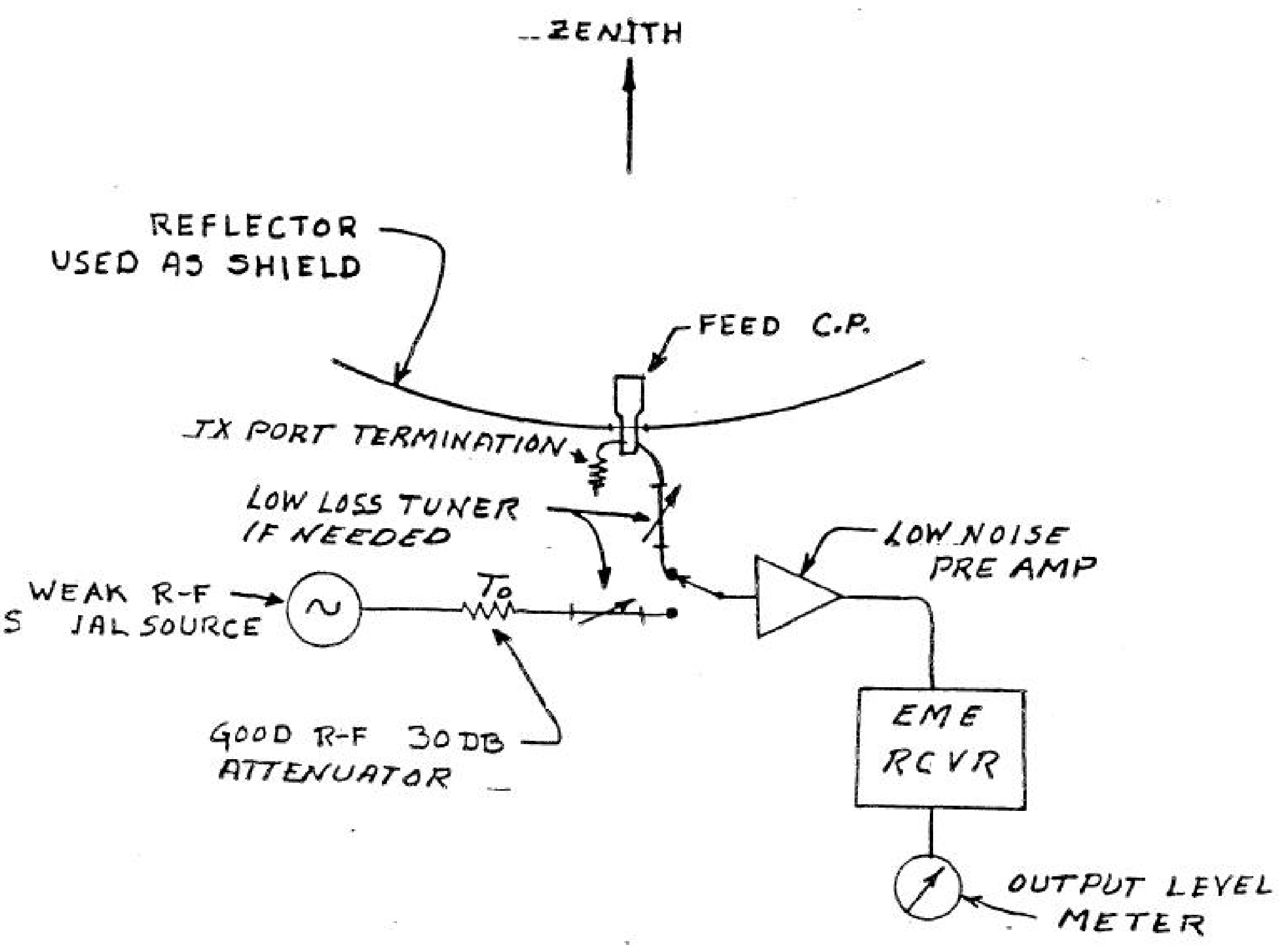

FIGURE 1